MONITORING PROGRAM FOR PHARMACEUTICALS, ILLEGAL SUBSTANCES, AND CONTAMINANTS IN FARMED FISH

Annual report for 2022

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Overvåkingsprogram for legemidler, ulovlige stoffer og miljøgifter i oppdrettsfisk

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This report summarises the monitoring data collected in 2022 on the status of illegal substances, pharmaceuticals and contaminants in Norwegian farmed fish. In 2022, a total of 15040 fish were sampled. Samples examined for illegal compounds were collected at all stages of farming and are representative of farmed fish under production. The samples were analysed for substances with anabolic effects or unauthorized substances. No residues of illegal compounds were detected. Samples tested for approved veterinary drugs and contaminants were collected at processing plants and are representative of Norwegian farmed fish ready for human consumption. Residues of the anti-sealice agents emamectin, lufenuron and imidacloprid were found. In addition, residues of cypermethrin and deltamethrin were detected; both substances used as chemical delousing, but also as plant protection agents. Residue concentrations for all samples were below the respective Maximum Residue Limits (MRLs). Other veterinary drugs, like antibiotics or drugs used against internal parasites were not found. No environmental contaminants were found above the EU maximum level.

Sammendrag (engelsk):

Denne rapporten oppsummerer overvåkingsresultatene fra 2022 for ulovlige stoffer, legemidler og miljøgifter i norsk oppdrettsfisk. I 2022 ble det tatt ut prøver av totalt 15 040 fisk. Prøver som ble analysert for ulovlige forbindelser, som stoffer med anabole effekter eller uautoriserte legemidler, ble tatt ut under alle livsstadier, og er representative for oppdrettsfisk under produksjon. Det ble det ikke detektert rester av ulovlige stoffer i noen av prøvene. Prøver som ble testet for godkjente veterinære legemidler og miljøgifter ble samlet inn på slakterier, og er representativt for norsk oppdrettsfisk som er klar for markedet. Rester av lusemidlene emamectin, lufenuron og imidakloprid ble funnet. I tillegg ble cypermetrin og deltametrin detektert, dette er stoffer som kan brukes både som plantevernmiddel og lusemiddel. Prøvene viste nivåer under de respektive grenseverdiene (MRLs). Andre veterinære legemidler, som antibiotika eller legemidler brukt mot invollsparasitter ble ikke funnet. Ingen miljøgifter ble funnet over EUs maksimumsgrenser.

Innhold

1 - Introduction

1.1 - Background

According to EU legislation (Regulation (EU) 2017/625, which from 2023 is supplemented with Regulation(EU) 2022/1644, Regulation (EU) 2022/1646, Regulation (EU) 2022/931 and Regulation (EU) 2022/932), all food producing animals should be monitored for certain substances and residues thereof. The following residues or substance groups are monitored in Norwegian farmed fish:

Group A Substances with anabolic effects and unauthorized substances:

A1: Stilbenes, derivatives and their salts and esters

A3: Steroids

A5: Beta-agonists

A6: Prohibited substances

Group B Veterinary drugs and contaminants:

B1: Antibacterial agents

B2a: Anthelmintics

B2c: Carbamates and pyrethroids

B2d: Sedatives

B3a: Organochlorine compounds

B3b: Organophosphorus compounds

B3c: Chemical elements

B3d: Mycotoxins

B3e: Dyes

B3f: Others

1.2 - Group A, Substances with anabolic effects and unauthorized substances

Fish tested for illegal compounds were collected at the farm by official inspectors from the Norwegian Food Safety Authority (NSFA), without prior notification to the farmers. Samples were taken at all stages of farming in order to represent farmed fish during production. Substances monitored in Group A include growth promoters like steroids and stilbenes, and unauthorized drugs. Unauthorized drugs considered most relevant for aquaculture are chloramphenicol, nitrofurans, metronidazole and dyes. Since the use of the dyes malachite green, crystal violet and brilliant green is not allowed for food producing species (Commission Regulation (EU) No. 37/2010), they are considered Group A substances and hence monitored in samples throughout the production chain. However, according to Regulation (EU) 2017/625, these dyes belong to the group B3e. Thus, in order to fulfill criteria for group B sampling, some of the samples assigned to analysis of dyes were also collected at the slaughterhouse.

To ensure harmonized levels for the control of unauthorized substances, the analytical methods should meet a minimum required performance limits (MRPLs) set by the European Union (Commission Decision 2003/181/EC; CRL, 2007; European Commission, 2003), and European reference laboratories (EU-RLs) (Commission Decision 2003/181/EC; CRL, 2007; European Commission, 2003). Table 1 gives an overview of MRPLs of relevant compounds.

1.3 - Group B, veterinary drugs

In order to protect public health, current EU legislation (Commission Regulation (EU) No. 37/2010) provisions the assignment of Maximum Residue Limits (MRLs) for all legally applied pharmacologically active substances in products intended for human consumption. An MRL denotes the highest permitted residual concentration of a legally applied veterinary drug and is evaluated for each substance and each food product individually. Consumption of food with drug residues below the MRL should not pose a health risk to the consumer. For fish, the MRLs are set for muscle and skin in natural proportions. Samples examined for veterinary drugs were collected from fish at processing plants and the samples are representative of fish ready to be placed on the market for human consumption.

1.4 - Group B, contaminants

Samples examined for contaminants were collected from fish at processing plants and are representative of fish ready for human consumption. The EU (Commission Regulation (EC) No. 1881/2006) has set a Maximum limit (ML) for some of the contaminants in fish, while for others, such as pesticides, polycyclic aromatic hydrocarbons (PAH), perfluorocarbons (PFC) and brominated flame retardants (BFR), maximum limits have not been established.

2 - Material and methods

2.1 - Sampling

Samples were taken on fish farms or slaughterhouses, by official inspectors from the NFSA, in all fish-producing regions in Norway. The sampling plan was randomised according to season and region. In 2022, the monitoring program included Atlantic salmon (*Salmo salar*), rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), turbot (*Scophthalmus maximus*), Atlantic halibut (*Hippoglossus hippoglossus*), Arctic char (*Salvelinus alpinus*), Atlantic cod (*Gadus morhua*) and spotted wolffish (*Anarhichas minor*) .

Samples were transported to the Institute of Marine Research (IMR) in a frozen state. For most analyses, the Norwegian quality cut (NQC) was used (Johnsen et al., 2011). However, both NQC and individual liver samples were collected for analysis of antibiotics. Samples to be used for analyses of substances with anabolic effects or unauthorized substances also included small fish from early life stages, and in these cases, the whole fish except head, tail and gut were homogenised. The samples were analysed as pooled samples comprising five fish from the same cage/farm.

2.2 - Pre-treatment

Upon arrival at IMR the sample identification was anonymised for the analysts. A back-up sample was stored for all samples. Pooled samples of muscle from five fish from the same cage/farm were homogenised before analyses. Samples of liver were excised from the fish to be screened for residues of antimicrobial agents by the microbiological inhibition zone assay. Liver samples were examined individually, if residues were detected, the back-up sample of muscle was analysed by chemical methods. The maximum residue limits for veterinary drugs are set for muscle and skin in natural proportions (Commission Regulation (EU) No. 37/2010). Therefore, according to the analytical protocol, any detection of drug residues in the muscle or liver was followed by a re-analysis of the back-up sample, consisting of muscle and skin in natural proportions, in duplicate.

2.3 - Analytical methods

The laboratory routines and most of the analytical methods are accredited in accordance with the standard ISO 17025 (Table 1). A summary of the analytical methods and their limit of detection (LOD) or limit of quantification (LOQ) is shown in Table 1. The LOD is the lowest level at which the method is able to detect the substance, while the LOQ is the lowest level for a reliable quantitative measurement. For all methods, a sample blank and a quality control sample (QC) with a known composition and concentration of target analyte are included in each series. The methods are regularly verified by participation in inter laboratory proficiency tests, or by analysing certified reference material (CRM), where such exist.

Table 1. Summary of analytical methods[1].

Group of substances	Analyte	Method	LOD (µg/kg w.w.)	LOQ (µg/kg w.w.)	Level of action (µg/kg w.w.)	Laboratory
A1 Stilbenes	Diethylstilbestrol	LC-MS/MS	1		Presence	Eurofins
	Dienestrol		1			
	Hexestrol		1			
	B-Estradiol		1			
	α-Estradiol		1			
	Estriol		1			
	Estrone		1			
	Ethinyl estradiol		1			
A3 Steroids	α-nandrolon	LC-MS/MS	1		Presence	Eurofins
	β-nandrolon		1			
	α-trenbolon		1			
	β-trenbolon		1			
	Trenbolone-acetate		2			
	16-Hydroxy stanozolol		1			
	α -Boldenone		1			
	Boldenone		1			
	Chlor-Testosterone (Clostebol)		1			
	Epitestosterone		1			
	Methyl-Boldenone (Dianabol)		1			
	Methyltestosterone		1			
	Nortestosterone/ Nandrolone		1			
	Stanozolol		1			
	Testosterone		1			
	Testosterone-propionate		2			
	Brombuterol		0.10			
	Cimaterol		0.50			
	Cimbuterol		0.50			
	Clenbuterol		0.10			
	Clencyclohexerol		1.0			
	Clenpenterol		0.50			
	Clenproperol		0.50			

Group of substances	Analyte	Method	LOD (µg/kg w.w.)	LOQ (µg/kg w.w.)	Level of action (µg/kg w.w.)	Laboratory
A5 Beta-agonists	Fenoterol	LC-MS/MS	5.0		Presence	Eurofins
	Hydroxymethyl-clenbuterol		0.10			
	Isoxsuprine		0.50			
	Chlorbrombuterol		0.10			
	Mabuterol		0.10			
	Mapenterol		0.10			
	Metaproterenol (Orciprenalin)		10			
	Ractopamine		1.0			
	Ritodrine		0.50			
	Salbutamol		5.0			
	Salmeterol		5.0			
	Terbutaline		10			
	Tulobuterol		0.10			
	Zilpaterol		5.0			
A6 Annex IV substances	Chloramfenicol	LC-MS/MS	0.25		Presence	IMR
	Metronidazole	LC-MS/MS	0.3		Presence	
	Hydroxy-metronidazole		2.0			
	Nitrofuran AOZ	LC-MS/MS	0.5		Presence	
	Nitrofuran AHD		0.6		Presence	
	Nitrofuran AMOZ		0.4		Presence	
	Nitrofuran SEM		0.5		Presence	
B1 Antibacterial Substances Micro-biological method	Quinolones	3-plate Screening Method [2]	200		100-600	IMR
	Tetracyclines		200		100	
	Amphenicols		200		1000	
	Sulfonamides		400		100	
B1 Antibacterial substances Chemical method	Oxolinic acid	LC-MS/MS		40	100	IMR
	Flumequine			40	600	
	Enrofloxacin			10	100	
	Ciprofloxacin			10	100	
	Trimethoprim			2.0	50	
	Florfenicol			4.0	1000	
	Oxytetracycline	LC-MS/MS		30	100	Eurofins
	Praziquantel	LC-MS/MS		1-0	-	

Group of substances	Analyte	Method	LOD (µg/kg w.w.)	LOQ (µg/kg w.w.)	Level of action (µg/kg w.w.)	Laboratory
B2a Anthelmintics	Fenbendazole	LC-MS/MS		1.0	-	IMR/ Eurofins
	Emamectin	LC-MS/MS		2.0	100	
	Diflubenzuron	LC-MS/MS		1.0	10	
	Teflubenzuron			1.0	500	
	Hexaflumuron			1.0	500	
	Lufenuron			1.0	1350	
	Abamectin	LC-MS/MS		2	-	Eurofins
	Doramectin			2	-	
	Emamectin B1a			2	100	
	Eprinomectin			2	50	
	Ivermectin			2	-	
	Moxidectin			2	-	
	Isoeugenol [3]	GC-FID		50	6000	
	Imidacloprid [3]	LC-MS/MS		4	600	Eurofins
B2c Carbamates and pyrethroids	Bifenthrin	GC-MS/MS		0.51-1.0	-	IMR
	Cyfluthrin			0.51-1.0	-	
	Cypermethrin			0.51-1.0	50	
	Deltamethrin			0.51-1.0	10	
	Fenvalerate			0.51-1.0	-	
	Lambda-Cyhalothrin			0.51-1.0	-	
	Permethrin			1.0-2.1	-	
B3a Organo-chlorine compounds	Dioxins and dl-PCBs	HRGC-HRMS		0.0000010-0.11 ng TEQ/kg	6.5 ng TEQ/kg	IMR
	PCB-6	GC-MS GC-MS/MS		0.0052 – 0.040	75	
	Organochlorine pesticides	GC-MS/MS		0.020-2.1	-	
B3b Organo-phosphorus compounds	Azametiphos	LC-MS/MS		10	-	IMR
	Dichlorvos					
	Chlorpyriphos Chlorpyrifos-methyl	GC-MS/MS		0.020-0.041 0.10-0.21	-	
	Pirimiphos-methyl			0.10-0.21	-	
	Lead			0.005- 0.010 mg/kg	0.3 mg/kg	
	Cadmium			0.001- 0.002 mg/kg	0.05 mg/kg.	
	Arsenic			0.002-0.003 mg/kg	-	

Group of substances	Analyte	Method	LOD (µg/kg w.w.)	LOQ (µg/kg w.w.)	Level of action (µg/kg w.w.)	Laboratory
B3c Chemical elements	Mercury	ICP-MS		0.001-0.002 mg/kg	0.5 mg/kg	IMR
	Cobalt			0.005-0.010 mg/kg	-	
	Chromium			0.006-0.010 mg/kg	-	
	Copper			0.1 mg/kg	-	
	Iron			0.1 mg/kg	-	
	Manganese			0.03 mg/kg	-	
	Molybdenum			0.02-0.04 mg/kg	-	
	Nickel			0.06-0.10 mg/kg	-	
	Selenium			0.01 mg/kg	-	
	Silver			0.002-0.004 mg/kg	-	
	Vanadium			0.001-0.002 mg/kg	-	
	Zinc			0.5 mg/kg	-	
	Inorganic arsenic	LC-ICP-MS		2-3	-	
	Methylmercury	GC-ICP-MS		1	-	
	Tributyltin	GC-ICP-MS		0.04-0.08	-	
	Arsenobetaine	LC-ICP-MS		0.004	-	
	Arsenocholine			0.3	-	
	Dimethylarsenate			0.001	-	
	Tetramethylarsonium			0.003-0.004	-	
	Trimethylarsine oxide			0.001-0.002	-	
	Trimethylarsine propanoate			0.0009-0.001	-	
B3d Mycotoxins	Beauvericin, Enniatin A, A1, B and B1	LC-MS/MS		10	-	Eurofins
B3e, Dyes	Malachite green	LC-MS/MS	0.15		Presence	IMR
	Leuco malachite green		0.15			
	Crystal violet		0.30		Presence	
	Leuco crystal violet		0.15		Presence	
	Brilliant green		0.15		Presence	
	PBDE	GC-MS		0.00052-0.052	-	IMR
	HBCD	LC-MS/MS		0.006-0.03	-	Eurofins

Group of substances	Analyte	Method	LOD (µg/kg w.w.)	LOQ (µg/kg w.w.)	Level of action (µg/kg w.w.)	Laboratory
B3f, Others	TBBPA	GC-MS		0.04-0.2	-	Eurofins
	PAH	GC-MS/MS		0.02-0.7	-	IMR
	PFC	LC-MS/MS		0.2.1.0	-	IMR
	Ethoxyquin	HPLC-FLD		0.001	-	IMR
	Ethoxyquin dimer			0.005	-	

[1] All methods used muscle as sample matrix except for microbiological methods for antibacterial substances (B1), where liver was used. [2] Only screening method, positive results must be confirmed by a chemical method. [3] Not accredited.

3 - Results

3.1 - Substances with anabolic effects and unauthorized substances

In 2022, a total of 1074 pooled fillet samples (5 fish/sample) were tested for residues of illegal substances, including stilbenes (142 pooled samples), steroids (141 pooled samples), beta agonists (142 pooled samples) and unauthorized veterinary drugs (649 pooled samples). The samples were mainly taken from Atlantic salmon, but also samples from rainbow trout, Atlantic cod, brown trout and Arctic char were analysed. With regards to illegal substances, the samples are monitored for and evaluated towards presence. No residues of unauthorized compounds were detected in any of the samples. The individual substances included in the monitoring of these substance groups, analytical methods, and legal action limits are listed in Table 1, Materials and Methods.

Table 2. Substances with anabolic effect and unauthorized substances in fillets of farmed fish. The table shows the total number of samples analysed in 2022, number of samples per fish species and number of positive samples for residues of illegal substances included in the monitoring.

	Total number of pooled samples [1]	*Species*					Number of positive samples
		Atlantic salmon	Rainbow trout	Brown trout	Atlantic cod	Arctic char	
A1 Stilbenes [2]	**142**	129	10	1	0	2	not detected
A3 Steroids [2]	**141**	127	11	1	1	1	not detected
A5 Beta-agonists [2]	**142**	130	9	1	1	1	not detected
A6 Annex IV substances							
Dyes[2]	**222[3]**	194	21	2	2	3	not detected
Chloramphenicol	**142**	130	8	1	0	3	not detected
Metronidazole, Metronidazole hydroxide	**143**	132	8	1	1	1	not detected
Nitrofuranes (AHD, AOZ, AMOZ, SEM)	**142**	127	12	1	0	2	not detected

[1]Fillet from five fish per sample. [2] A list over all individual substances included in the monitoring, analytical methods, and legal action limits can be found in Chapter 2, Materials and Methods, Table 1. [3] Including both 141 pooled fillet samples of fish taken from production, and 81 pooled samples of fish taken at the slaughterhouse.

3.2 - Veterinary drugs

Samples analysed for veterinary drugs were collected from fish at processing plants, representing fish ready for human consumption. The maximum residue limit (MRL) for veterinary drugs is defined for muscle and skin in natural proportions (Commission Regulation (EU) No. 37/2010). Therefore, according to the analytical protocol, any detection of drug residues in a sample of muscle or liver would be followed by a re-analysis of the backup sample, consisting of muscle and skin in natural proportions, in duplicate.

3.2.1 - Group B1, Antibacterial agents

Antibacterial agents were monitored through a combination of a three-plate bioassay and chemical methods. The broad groups a) quinolones, b) amphenicols and tetracyclines and c) sulfonamides were screened in livers

of 1640 fish (Table 3). A total of 128 pooled fillet samples, representing 640 fish were analysed by chemical methods (Table 4). No residues were detected in any of the samples analysed.

Table 3. Antibacterial agents in liver of farmed fish. The table shows total number of pooled samples analysed in 2022, number of samples analysed per fish species, number of samples above LOQ (n >LOQ), and method LOQs for the screening for residues of four groups of broad-spectrum antibiotics in liver tissue.

Antibiotics [1]	Total number of pooled samples	Species						LOQ (µg/kg w.w.)
		Atlantic salmon	Rainbow trout	Arctic char	Atlantic cod	Brown trout	Turbot	
n	**328**	299	20	6	1	1	1	
Quinolones	*n >LOQ*	0						100
Sulfonamides	*n >LOQ*	0						400
Tetracyclines	*n >LOQ*	0						200
Amphenicols	*n >LOQ*	0						200

[1] No MRL established for liver

Table 4 . Antibacterial agents in fillets of farmed fish. The table shows the total number of pooled samples analysed in 2022, number of samples analysed per fish species, number of samples above the LOQ (n >LOQ), method LOQs, and legal maximum residue limits (MRLs) for residues of different antibacterial substances included in the monitoring.

Antibacterial agents	Total number of pooled samples	Species					LOQ (µg/kg w.w.)	MRL (µg/kg w.w.)
		Atlantic salmon	Rainbow trout	Atlantic cod	Atlantic halibut	Turbot		
n	**107**	95	5	5	1	1		
Ciprofloxacin	*n >LOQ*	0					10	100
Enrofloxacin	*n >LOQ*	0					10	100
Florfenicol	*n >LOQ*	0					4	1000
Flumequine	*n >LOQ*	0					40	600
Oxolinic acid	*n >LOQ*	0					40	100
Trimethoprim	*n >LOQ*	0					2	50
n	**21**	19	2	0	0	0		
Tetracycline	*n >LOQ*	0		-	-	-	30	100
Doxycycline	*n >LOQ*	0		-	-	-	30	100
Chlortetracycline	*n >LOQ*	0		-	-	-	30	100
Oxytetracycline	*n >LOQ*	0		-	-	-	30	100

3.2.2 - Group B2a, Anthelmintics

The residues of anthelmintics, such as anti-sea-lice agents (Table 5) and agents for treatment of endoparasites (Table 6) were monitored in a total of 520 pooled fillet samples, representing 2600 fish.

Residues of the anti-sea lice agent emamectin were detected in two out of 124 analysed samples, at concentrations of 3.9 and 7.8 µg/kg. The concentrations were below the MRL of 100 µg/kg (EU 37/2010).

Residues of lufenuron were found in two out of 113 analysed samples. The concentrations measured were 1.2 and 1.5 µg/kg and were below the MRL of 1350 µg/kg. Residues of imidacloprid were detected in two out of 118 samples analysed. The concentrations were 10 and 13 µg/kg, and were below the MRL of 600 µg/kg. Residues of other agents in this group were not detected in any of the samples.

Table 5. Anti-sea lice agents in fillet of farmed fish. The table shows the total number of pooled samples analysed in 2022, number of samples analysed per fish species, number of samples with residues above LOQ (n >LOQ), method LOQs, and legal maximum residue limits (MRL). Where residues above LOQ were detected, the maximum value measured (µg/kg w.w.) is given in the row underneath.

Anti-sealice agents	Total number of pooled samples	*Species*					LOQ (µg/kg w.w.)	MRL (µg/kg w.w.)
		Atlantic salmon	Rainbow trout	Arctic char	Brown trout	Atlantic cod		
n	**124**	117	5	1	1	0		
Emamectin	*n >LOQ*	2	0	0	0	-		
	Max value (µg/kg w.w.)	7.8	-	-	-	-	2	100
n	**16**	15	0	1	0	0		
Ivermectin	*n >LOQ*	0	-	0	-	-	2	-
Abamectin	*n >LOQ*	0	-	0	-	-	2	-
Doramectin	*n >LOQ*	0	-	0	-	-	2	-
Eprinomectin	*n >LOQ*	0	-	0	-	-	2	50
Moxidectin	*n >LOQ*	0	-	0	-	-	2	-
n	**113**	106	6	0	0	1		
Diflubenzuron	*n >LOQ*	0	0	-	-	0	1	10
Teflubenzuron	*n >LOQ*	0	0	-	-	0	1	500
Lufenuron	*n >LOQ*	2	0	-	-	0	1	1350
	Max value (µg/kg w.w.)	1.5	-	-	-	-		
Hexaflumeron	*n >LOQ*	0	0	-	-	0	1	500
Fluazuron	*n >LOQ*	0	0	-	-	0	1	200
n	**118**	111	6	0	0	1		
Imidacloprid	*n >LOQ*	2	0	-	-	0	4	600
	Max value (µg/kg w.w.)	13	-	-	-	-		
n	**50**	46	3	0	0	1		
Azamethiphos	*n >LOQ*	0	0	-	-	0	10	-
Dichlorvos	*n >LOQ*	0	0	-	-	0	10	-

Table 6. Agents against endoparasites in fillet of farmed fish. The table shows the total number of pooled samples analysed in 2022, number of samples analysed per fish species, number of samples above LOQ (n >LOQ), and method LOQs for different analyses of residues of praziquantel and fenbendazole (µg/kg w.w.). There is no legal maximum residue limit (MRL) established for either of these compounds in fish muscle.

	Total number of pooled samples	*Species*					LOQ (µg/kg w.w.)
		Atlantic salmon	Rainbow trout	Brown trout	Atlantic cod	Turbot	

n	**99**	91	5	1	1	1	
Praziquantel	n >LOQ	0					1
Fenbendazole	n >LOQ	0					1

3.2.3 - Group B2c, Carbamates and pyrethroids

In 2022, carbamates and pyrethroid substances were monitored in 197 samples, representing 985 fish (Table 7).

Table 7. Carbamates and pyrethroid substances in fillet of farmed fish. The table shows the total number of pooled samples analysed in 2022, number of samples analysed per farmed fish species, number of samples above LOQ (n >LOQ), and the median and maximum values for measured residues of carbamate and pyrethroid substances (µg/kg w.w.). The median was calculated when more 50% of the samples had values above LOQ. Where none of the samples had values above LOQ, the maximum value was set at LOQ. Method LOQs and legal maximum residue limits (MRL) for the different substances are given in the last two columns.

		Species					**LOQ (µg/kg w.w.)**	**MRL fin fish (µg/kg w.w.)**
	Total number of pooled samples	**Atlantic salmon**	**Rainbow trout**	**Arctic char**	**Atlantic cod**	**Atlantic halibut**		
n	**197**	178	15	2	1	1		
Cypermethrin	*n >LOQ*	41	6	2	0	0		
	Median	-	-	-	-	-		
	Max value	4.1	1.4	2	LOQ	LOQ	0.51- 1.0	50[1]
Deltamethrin	*n >LOQ*	2	0	1	0	0		
	Median	-	-	-		-		
	Max value	1.2	LOQ	1.5	LOQ	LOQ	0.51- 1.0	10
Bifenthrin	*n >LOQ*	0	0	0	0	0		
	Median	-	-	-	-	-		
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.51- 1.0	-
Cyfluthrin	*n >LOQ*	0	0	0	0	0		
	Median	-	-	-	-	-		
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.51- 1.0	-
Fenvalerat	*n >LOQ*	0	0	0	0	0		
	Median	-	-	-	-	-		
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.51- 1.0	-
Lambda-Cyhalothrin	*n >LOQ*	0	0	0	0	0		
	Median	-	-	-	-	-		
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.51- 1.0	-
Permethrin	*n >LOQ*	0	0	0	0	0		
	Median	-	-	-	-	-		
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	1.0- 2.1	-

[1] MRL established for *Salmonidae* only (muscle and skin in natural proportions).

Cypermethrin was detected in 41 out of 178 pooled fillet samples of Atlantic salmon, 6 out of 15 samples of rainbow trout, and both samples of Arctic char analysed. Residues of deltamethrin were found in two samples of

salmon and one sample of Arctic char.

Both cypermethrin and deltamethrin are synthetic pyrethroid substances, used as pharmaceutical delousing agent applied as bath treatment in aquaculture farm cages, but also as insecticide in large-scale commercial agricultural applications. Residues of cypermethrin and deltamethrin in fish may therefore also originate from transfer via plant-based ingredients in fish feed.

There are no pesticide MRLs established for cypermethrin or deltamethrin in fish muscle (EFSA, 2015, 2023). The maximum levels of cypermethrin measured were 4.1 µg/kg in salmon, 1.4 µg/kg in rainbow trout, and 2 µg/kg in Arctic char, and were all below the MRL of 50 µg/kg (EU 37/2010), which is established for cypermethrin residues from veterinary drugs. The MRL for deltamethrin used as veterinary drug is established at 10 µg/kg for fin fish. The maximum level of deltamethrin (1.5 µg/kg in Arctic char) detected was below this MRL.

None of the other carbamate or pyrethroid substances included in the monitoring, were detected in any of the samples.

3.2.4 - Group B2d, Sedatives

No residues of isoeugenol or eugenol were found in any of the 50 samples analysed for these sedatives (Table 8).

Table 8. Sedatives in fillet of farmed fish. The table shows the total number of pooled samples analysed in 2022, number of samples analysed per farmed fish species, and number of samples above LOQ (n >LOQ), method LOQs and legal maximum limits (MRLs) for isoeugenol and eugenol measured in fish fillets (µg/kg w.w.).

Sedatives	Total number of pooled samples	*Species*				LOQ (µg/kg w.w.)	MRL (µg/kg w.w.)
		Atlantic salmon	Rainbow trout	Brown trout	Atlantic cod		
n	**50**	46	2	1	1		
Isoeugenol	*n >LOQ*	0				50	6000
Eugenol	*n >LOQ*	0				50	-

3.3 - Contaminants

Samples analysed for contaminants were collected from fish at processing plants and are representative of fish ready for human consumption.

3.3.1 - Group B3a, Organochlorine compounds

The levels of organochlorine compounds were determined in 304 pooled samples in 2022. The results are summarised in Tables 9 to 11.

3.3.1.1 - Organochlorine pesticides

For several of the pesticides, the amount present is calculated as a sum including metabolites or transformation products (EU DG SANTE, 2017). The results for these groups of pesticides are presented in Table 9. To calculate the sum of the components, conversion factors (Table A1, Appendix) are used to adjust for different molecular weights (EU DG SANTE, 2017). The sums in Table 9 were calculated according to the upper bound (UB) formula. For DDT and Chlordane levels were calculated as the sums of all measured metabolites, as well as the sums of metabolites according to the legal residue definitions established through Reg. (EC) No

149/2008. When using UB calculations, the numerical value of LOQ is used as a concentration value for each non-quantified analyte. UB thus represents a “worst case scenario”. As an example, all measurements of endosulfan are below LOQ, however, a sum is generated based on the LOQ-values. The results for the other organochlorine pesticides are summarised in Table 10.

There are currently no MRLs established in fish fillet for any of the listed pesticides (EU, 2014).

Table 9. Median and maximum (Max) concentrations of the sum of certain organochlorine pesticides and their metabolites in fillet of farmed fish (µg/kg w.w.). The values are calculated as upper bound and adjusted for molecular weights.

Pesticide		Atlantic salmon	Rainbow trout	Arctic char	Atlantic cod	Atlantic halibut
Sum	*n*	178	15	2	1	1
DDT	*Median (UB)*	3.5[1] (3.4)[2]	3.7[1] (3.6)[2]	3.9[1] (3.7)[2]	-	-
	Max (UB)	11[1] (10)[2]	6.3[1] (6.0)[2]	4.7[1] (4.6)[2]	0.33[1] (0.29)[2]	4.7[1] (4.5)[2]
Endosulfane	*Median (UB)*	2.2	2.2	2.2	-	-
	Max (UB)	2.2	2.2	2.2	1.1	2.2
Aldrin and dieldrin	*Median (UB)*	1.4	1.3	1.5	-	-
	Max (UB)	3.6	3.0	1.8	0.41	1.1
Chlordane	*Median (UB)*	0.60[3] (0.40)[4]	0.59[3] (0.39)[4]	0.67[3] (0.47)[4]	-	-
	Max (UB)	1.9[3] (1.5)[4]	1.5[3] (1.3)[4]	0.83[3] (0.64)[4]	0.25[3] (0.15)[4]	0.69[3] (0.50)[4]
Heptachlor	*Median (UB)*	1.2	1.2	1.2	-	-
	Max (UB)	1.4	1.3	1.2	0.6	1.2
Toxaphene	*Median (UB)*	1.8	1.8	2.1	-	-
	Max (UB)	6.7	4.0	2.4	0.91	2.1

1 DDT (sum of p,p-DDT, o,p-DDT, p,p-DDD, o,p-DDD, p,p-DDE,and o,p-DDE expressed as DDT). **2** Legal residue definition according to Reg. (EC) No 149/2008: DDT (sum of p,p´-DDT, o,p´-DDT, p-p´-DDE and p,p´-TDE (DDD) expressed as DDT). **3** Chlordane (sum of cis- and trans-isomers and oxychlordane expressed as chlordane). **4** Legal residue definition according to Reg. (EC) No 149/2008: Chlordane (sum of cis- and trans-chlordane).

Table 10. Pesticides in fillets of farmed fish (µg/kg w.w.). The table shows the number of samples analysed in 2022 per species, number of samples above LOQ (n >LOQ), median, and maximum measured value (Max value). The median was calculated when more 50% of the samples had values above LOQ. Where none of the samples had values above LOQ, the maximum value was set at LOQ. Method LOQs for the different compounds are given in the last column.

Pesticide		Atlantic salmon	Rainbow trout	Arctic char	Atlantic cod	Atlantic halibut	LOQ (µg/kg w.w.)
	n	178	15	2	1	1	
α-Hexachlorocyclo- hexane	*n >LOQ*	178	15	2	0	0	
	Median	0.098	0.091	0.063	-	-	
	Max value	0.15	0.13	0.065	LOQ	LOQ	0.020-0.040
β-Hexachlorocyclo- hexane	*n >LOQ*	178	15 0.	2	0	1	
	Median	0.10	0.088	0.090	-	-	
	Max value	0.52	0.28	0.10	LOQ	0.049	0.020-0.040

Pesticide		Atlantic salmon	Rainbow trout	Arctic char	Atlantic cod	Atlantic halibut	LOQ (µg/kg w.w.)
γ-Hexachlorocyclo- hexane (Lindane)	*n >LOQ*	129	12	0	0	0	
	Median	0.046	0.049	-	-	-	
	Max value	0.092	0.079	LOQ	LOQ	LOQ	0.020-0.040
Hexachlorobenzene	*n >LOQ*	178	15	2	0	1	
	Median	0.73	0.67	0.86	-	-	
	Max value	2.4	2.1	1.2	LOQ	0.64	0.10-0.20
Pentachlorobenzene	*n >LOQ*	0	0	0	0	0	
	Median	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.51- 1.0
Toxaphene Parlar 32	*n >LOQ*	0	0	0	0	0	
	Median	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.51- 1.0
Toxaphene Parlar 40+41	*n >LOQ*	0	0	0	0	0	
	Median	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	1.0-2.0
Trans-Nonachlor	*n >LOQ*	176	14	2	0	1	
	Median	0.42	0.49	0.45	-	-	
	Max value	2.2	1.3	0.61	LOQ	0.71	0.51- 1.0
Endrin	*n >LOQ*	0	0	0	0	0	
	Median	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.51- 1.0
Endrin-ketone	*n >LOQ*	0	0	0	0	0	
	Median	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.51- 1.0
Mirex	*n >LOQ*	22	3	0	0	1	
	Median	-	-	-	-	-	
	Max value	0.12	0.070	LOQ	LOQ	0.074	0.020-0.41
	n >LOQ	0	0	0	0	0	
	Median	-	-	-	-	-	

Isodrin **Pesticide**		**Atlantic salmon**	**Rainbow trout**	**Arctic char**	**Atlantic cod**	**Atlantic halibut**	**LOQ (µg/kg w.w.)**
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.51- 1.0

3.3.1.2 - Dioxin, dl-PCBs and PCB-6

The levels of dioxin (PCDD+PCDF), dl-PCBs and PCB-6 in farmed fish are shown in Table 11. The data is mainly represented by Atlantic salmon, but in 2022 also samples from rainbow trout, Arctic char, Atlantic cod, turbot and Atlantic halibut were examined. The sums of dioxins, dioxins + dl-PCBs and PCB-6 are calculated as upper bound (Commission Regulation (EU) No. 1259/2011). Accordingly, the numerical LOQ values were used for congeners with levels below LOQ.

The levels of dioxins and dl-PCBs are reported as ng toxic equivalents 2005 (TEQ05)/kg and represent the sum of 17 different PCDD/F and 12 dl-PCBs where each congener was multiplied by a Toxic Equivalency Factor (TEF). TEF values are determined by the World Health Organization (WHO), and the toxicity of each congener is expressed relative to the most toxic form of dioxin, which has a TEF value of 1 (Commission Regulation (EU) No. 1259/2011; Van den Berg et al., 2006).

In 2022, dioxin levels found in fish fillet were somewhat lower than in the previous year. For salmon, the median of the sum of dioxins was 0.12 ng TEQ/kg w.w. The maximum value found in salmon (0.34 ng TEQ/kg w.w.) was below the EU maximum level of 3.5 ng TEQ/kg w.w. The median of the sum of all 29 PCDD/F and dl-PCBs was 0.32 ng TEQ/kg w.w for salmon (0.04 ng TEQ/kg w.w. lower than in 2020) and 0.37 ng TEQ/kg w.w for rainbow trout similar to 2021. The highest result for sum dioxin and dl-like PCBs was 0.79 ng TEQ/kg w.w., measured in tubot. All measured values were below the EU maximum level of 6.5 ng TEQ/kg w.w. The median of PCB-6 for salmon was 2.6 µ g/kg w.w and 3.6 in rainbow trout, with maximum concentrations of 5.7 and 5.1 µ g/kg w.w, respectively. For PCB-6, a maximum level is set at 75 µ g/kg w.w. in the EU.

Table 11. Median and maximum (Max value) concentrations of the sum of dioxins (ng TEQ/kg w.w.), sum of dioxin and dioxin-like PCBs (dl-PCBs; ng TEQ/kg w.w.) and PCB-6 (µg/kg w.w.) in fillets of different farmed fish species in 2022. All concentrations are calculated as upper bound (UB). The EU maximum levels established for fish muscle are given in the last column.

		Atlantic salmon	**Rainbow trout**	**Arctic char**	**Atlantic cod**	**Turbot**	**Atlantic halibut**	**EU Maximum Level**
	n	98	4	2	1	1	1	
Sum dioxins (ng TEQ/kg w.w.)	*Median*	0.12	0.13	0.15	-	-	-	
	Max value	0.34	0.19	0.16	0.01	0.22	0.33	3.5
Sum dioxin + dl-PCBs (ng TEQ/kg w.w.)	*Median*	0.32	0.37	0.33	-	-	-	
	Max value	0.74	0.65	0.41	0.02	0.79	1.1	6.5
PCB-6 (µg/kg w.w.)	*Median*	2.6	3.6	2.5	-	-	-	
	Max value	5.7	5.1	3.9	0.12	6.6	8.2	75

3.3.2 - Group B3b, Organophosphorous compounds

Organophosphorous pesticide residues, chlorpyriphos, chlorpyriphos-methyl and pirimiphos-methyl, were determined in 197 pooled fillet samples, representing fillet of 985 fish (Table 12). No residues of chlorpyriphos or chlorpyriphos-methyl were detected in any of the samples. Pirimiphos-methyl was detected in 5 of 178 samples of Atlantic salmon. The maximum concentration was 0.60 µg pirimiphos-methyl/kg w.w.. There is currently no MRL established for pirimiphos-methyl in fish fillet (EU, 2014). No residues were detected in samples of rainbow trout, Arctic char, Atlantic cod or Atlantic halibut.

Table 12. Residues of organophosphorous compounds (µg/kg w.w.) in fillets of different species of farmed fish. The table shows the number of samples analysed in 2022 per species, number of samples above LOQ (n >LOQ) and the maximum measured value (Max value). Where none of the samples had values above LOQ, the maximum value was set at LOQ. Method LOQs for the different compounds are given in the last column.

Compound		Atlantic salmon	Rainbow trout	Arctic char	Atlantic cod	Atlantic halibut	LOQ (µg/kg w.w.)
	n	*178*	*15*	*2*	*1*	*1*	
Chlorpyriphos	*n >LOQ*	0	0	0	0	0	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.020-0.041
Chlorpyriphos-methyl	n >LOQ	0	0	0	0	0	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.10-0.21
Pirimiphos-methyl	n >LOQ	5	0	0	0	0	
	Max value	0.60	LOQ	LOQ	LOQ	LOQ	0.10-0.21

3.3.3 - Group B3c, Chemical elements

In 2022, monitoring of the levels of chemical elements, such as arsenic (and inorganic arsenic), total mercury in addition to methylmercury, cadmium, lead included 71 samples of Atlantic salmon, 5 samples of rainbow trout, 2 samples of Atlantic cod, one sample of turbot and one sample of Arctic char (Table 13). Mono-, di- and tributyltin were analyzed in 54 samples of Atlantic salmon, 5 samples of rainbow trout, 2 samples of Atlantic cod and one sample of Arctic char.

The concentrations of total mercury were found below the EU maximum level, which is set at 0.50 mg/kg w.w. for these species. The highest concentrations of total mercury were 0.06 mg/kg w.w. in salmon, and 0.08 mg/kg w.w. in Atlantic cod (Table 13). Mercury was mainly present as methylmercury, which was assessed in 21 samples of Atlantic salmon (Table 14).

Table 13. Chemical elements (mg/kg w.w.) in fillets of different farmed fish species. The table shows the number of samples analysed, number of samples with values above LOQ (n>LOQ), the median, and the maximum concentration measured (Max value). The median was calculated as upper bound, when more 50% of the samples had values above LOQ. Where none of the samples had values above LOQ, the maximum value was set at LOQ.

Element		**Atlantic salmon**	**Rainbow trout**	**Atlantic cod**	**Turbot**	**Arctic char**	**LOQ**	**EU ML**
	n	***70*** [1]	***5***	***2***	***1***	***2***		
Total Mercury (mg/kg w.w.)	*n >LOQ*	71	5	2	1	2		
	Median	0.014	0.016	0.063	-	0.022		
	Max value	0.060	0.069	0.081	0.071	0.024	0.001-0.002	0.50
Total Arsenic (mg/kg w.w.)	*n >LOQ*	71	5	2	1	2		
	Median	0.60	0.65	1.4	-	1.7		
	Max value	2.1	1.3	1.8	3.4	1.9	0.002-0.003	n.a.
Cadmium (mg/kg w.w.)	*n >LOQ*	0	0	0	1	0		
	Median	-	-	-	-	-		
	Max value	LOQ	LOQ	LOQ	0.0029	LOQ	0.001-0.002	0.05
Lead (mg/kg w.w.)	*n >LOQ*	1	0	0	0	0		
	Median	-	-	-	-	-		
	Max value	0.022	LOQ	LOQ	LOQ	LOQ	0.005-0.01	0.30
Cobalt (mg/kg w.w.)	*n >LOQ*	0	0	0	0	0		
	Median	-	-	-	-	-		
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.005-0.01	n.a.
Chromium (mg/kg w.w.)	*n >LOQ*	13	0	0	0	2		
	Median	-	-	-	-	0.031		
	Max value	0.087	LOQ	LOQ	LOQ	0.054	0.006-0.01	n.a.
Copper (mg/kg w.w.)	*n >LOQ*	70	5	2	1	2		
	Median	0.39	0.34	0.19	-	0.41		
	Max value	0.90	0.46	0.20	0.19	0.48	0.10	n.a.
Iron (mg/kg w.w.)	*n >LOQ*	70	5	2	1	2		
	Median	2.8	2.5	0.85	-	2.5		
	Max value	4.0	3.2	0.87	0.57	3.0	0.10	n.a.

Element		Atlantic salmon	Rainbow trout	Atlantic cod	Turbot	Arctic char	LOQ	EU ML
Manganese (mg/kg w.w.)	*n >LOQ*	70	5	2	1	2		
	Median	0.078	0.071	0.13	-	0.066		
	Max value	0.35	0.075	0.16	0.34	0.070	0.030	n.a.
Molybdenum (mg/kg w.w.)	*n >LOQ*	0	0	0	0	0		
	Median	-	-	-	-	-		
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.02-0.04	n.a.
Nickel (mg/kg w.w.)	*n >LOQ*	0	0	0	0	0		
	Median	-	-	-	-	-		
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.06-0.1	n.a.
Selenium (mg/kg w.w.)	*n >LOQ*	71	5	2	1	2		
	Median	0.17	0.28	0.26	-	0.24		
	Max value	0.39	0.30	0.28	0.20	0.25	0.01	n.a.
Silver (mg/kg w.w.)	*n >LOQ*	8	2	0	0	0		
	Median	-	-	-	-	-		
	Max value	0.014	0.004	LOQ	LOQ	LOQ	0.002-0.004	n.a.
Vanadium (mg/kg w.w.)	*n >LOQ*	18	0	0	0	0		
	Median	-	-	-	-	-		
	Max value	0.016	LOQ	LOQ	LOQ	LOQ	0.001-0.002	n.a.
Zinc (mg/kg w.w.)	*n >LOQ*	70	5	2	1	2		
	Median	3.9	3.8	4.3	-	4.6		
	Max value	5.0	4.4	4.5	8.0	4.8	0.5	n.a.
	n	***21***						
Inorganic arsenic (µg/kg w.w.)	*n >LOQ*	0						
	Median	-						
	Max value	LOQ					2-3	

[1] As, Cd, Hg, Pb, Se: 71 analysed samples

Cadmium in all Atlantic salmon samples, Atlantic cod, Arctic char and rainbow trout samples was below the LOQ. Only one sample of turbot had cadmium at a level of 0.003 mg/kg w.w. in the fillet which is well below the EUs maximum level of 0.05 mg/kg w.w. (Commission Regulation (EC) No. 1881/2006).

Arsenic is determined as “total arsenic”, comprising the sum of all arsenic species. In addition, inorganic arsenic was analyzed in 21 of the Atlantic salmon samples. The median level of total arsenic in Atlantic salmon was 0.60 mg/kg w.w., and, same as in the previous year, the highest concentration measured was 2.1 mg/kg w.w. (Table 13). The median and maximum concentration of Arsenic in rainbow trout samples were 0.65 and 1.3 mg/kg w.w respectively. The concentrations of inorganic arsenic were below the LOQ in all samples measured (Table 13). In addition to total arsenic and inorganic arsenic, in 2022, the levels of 6 organo-arsenic compounds were measured in 10 salmon samples (Table 14). There is currently no EU upper limit for arsenic in fish fillets.

Lead was determined only in one sample of Atlantic salmon (0.02) and in remaining samples of Atlantic salmon, all samples of rainbow trout, Atlantic cod, Arctic char and turbot the concentration of lead was below LOQ and well below the EU maximum level, which is currently set at 0.30 mg/kg w.w. in muscle meat of fish (Commission

Regulation (EC) No. 1881/2006).

Eleven additional chemical elements were analyzed in addition to the above-mentioned elements. There is currently no EU-limit established for any of these elements. Copper, iron, manganese, selenium and zinc were found at levels above LOQ in all samples analyzed (Table 13), with median values similar to the year before. The maximum concentrations among all 81 samples were 0.9 mg copper/kg, 4.0 mg iron/kg, 0.35 mg manganese/kg, 0.71 mg selenium/kg and 8.0 mg zinc/kg, respectively. The maximum concentration of selenium in Atlantic salmon was higher than previous year (0.28 mg/kg w.w.). Cobalt and nickel were not detected in any of the analyzed samples. Chromium and vanadium were detected in 15 and 18 out of 81 samples, respectively. The highest concentrations were 0.087 mg chromium/kg and 0.016 mg vanadium/kg (both salmon) in 2022.

Mono-, di- and tributyltin were monitored in a total of 62 pooled fillet samples of Atlantic salmon, rainbow trout, Atlantic cod and Arctic char. There is currently no EU upper limit for tin in fish fillet. Monobutyltin was found at levels above LOQ in 9 samples, with the maximum concentrations of 1 µg/kg w.w. and 0.7 µg/kg w.w. in salmon and rainbow trout, respectively. Concentration of dibutyltin was bellow LOQ (0.2 µg/kg w.w.) in all samples except one sample of Atlantic salmon which contained 0.1 µg/kg w.w. A total of 16 samples contained tributyltin above the LOQ, with the highest measured level of 0.2 µg/kg w.w. found in both Atlantic salmon and rainbow trout (median 0.2 µg/kg w.w.).

Table 14. Organic metal compounds (mg/kg w.w.) in fillets of different farmed fish species. The table shows the number of samples analysed per species, number of samples with values above LOQ (n > LOQ), the median, and the maximum concentration measured (Max value). The median was calculated as upper bound, when more 50% of the samples had values above LOQ. Where none of the samples had values above LOQ, the maximum value was set at LOQ.

Element		**Atlantic salmon**	**Rainbow trout**	**Atlantic cod**	**Arctic char**	**LOQ**	**EU ML**
	n	***21***					
Methyl-mercury (mgHg/kg w.w.)	*n >LOQ*	21					
	Median	0.013					
	Max value	0.061				0.001	n.a.
	n	***10***					
Arsenobetaine (mg/kg w.w.)	*n >LOQ*	10					
	Median	0.3					
	Max value	0.6				0.004	n.a.
Arsenocholine (mg/kg w.w.)	*n >LOQ*	0					
	Median	-					
	Max value	LOQ				0.3	n.a.
Dimethylarsinate (mg/kg w.w.)	*n >LOQ*	10					
	Median	0.008					
	Max value	0.01				0.001	n.a.
Tetramethyl Arsonium Ion (mg/kg w.w.)	*n >LOQ*	0					
	Median	-					
	Max value	LOQ				0.003-0.004	n.a.
Trimethylarsine oxide (mg/kg w.w.)	*n >LOQ*	1					
	Median	-					
	Max value	0.001				0.001-0.002	n.a.
Trimethylarsoniopropionate (mg/kg w.w.)	*n >LOQ*	0					
	Median	-					
	Max value	LOQ				0.0009-0.001	n.a.
	n	***54***	***5***	***2***	***1***		
Monobutyltin (µg Sn/kg w.w.)	*n >LOQ*	8	1	0	0		
	Median	-	-	-	-		

	Max value	1.0	0.7	LOQ	LOQ	0.4-0.5	n.a.
Dibutyltin (µg Sn/kg w.w.)	*n >LOQ*	1	0	0	0		
	Median	-	-	-	-		
	Max value	0.1	LOQ	LOQ	LOQ	0.2-0.5	n.a.
Tributyltin (µg Sn/kg w.w.)	*n >LOQ*	12	4	0	0		
	Median	-	0.1	-	-		
	Max value	0.2	0.2	LOQ	LOQ	0.06-0.09	n.a.

3.3.4 - Group B3d, Mycotoxins

Toxins produced by mould, also known as mycotoxins, have long been a known risk in human food and land animal feed. However, as a changing climate promotes unfavourable storage conditions and the portion of plant-based ingredients in fish feed has increased over the past decades, these toxins are becoming more common in fish feed as well. This presents challenges to the health of farmed fish on the one hand, on the other hand occurrence and accumulation of mycotoxins in edible tissues of farmed fish need to be monitored to ensure food safety. The mycotoxins enniatin A, enniatin A1, enniatin B, enniatin B1 and beauvericin have been monitored regularly in fillet samples of farmed fish as part of the monitoring programme. In 2022, 100 pooled fillet samples were measured. No residues of these mycotoxins were detected in any of the samples (Table 15).

Table 15. Mycotoxins in fillets of different farmed fish species (µg/kg w.w.). The table shows the number of samples analysed per species, number of samples with values above LOQ (n >LOQ), and method LOQs for beauvericin and enniatin.

Mycotoxins		Atlantic salmon	Rainbow trout	Brown trout	Arctic char	Atlantic cod	LOQ *(µg/kg w.w.)*
	n	***86***	***10***	***1***	***1***	***2***	
Beauvericin	*n >LOQ*	0					10
Enniatin A	*n >LOQ*	0					10
Enniatin A1	*n >LOQ*	0					10
Enniatin B	*n >LOQ*	0					10
Enniatin B1	*n >LOQ*	0					10

3.3.5 - Group B3f, others

The group “B3f, others” is a group not required for finfish products by Regulation (EU) 2017/625, but are deemed relevant for analyses in Norwegian aquaculture fish by the NFSA and IMR, because these undesirable compounds are present in the environment and may affect food safety. The monitoring program currently includes brominated flame retardants (BFR), perfluorinated compounds (PFC), polyaromatic hydrocarbons (PAHs), and since 2018 also the technological feed additive ethoxyquin (EQ) and its main transformation product ethoxyquin dimer (EQDM) under this group.

3.3.5.1 - Brominated flame retardants

PBDEs were measured in 107 pooled fillet samples (Table 16) . HBCD and TBBPA were analysed in in 100 pooled fillet samples (Table 17). There is currently no EU maximum limit for BFRs in food.

Table 16. Polybrominated diphenyl ethers (PBDEs) (µg/kg w.w) in fillets of different farmed fish species. The table shows the number of samples analysed per species, number of samples with values above LOQ (n > LOQ), the median and the maximum concentration measured (Max value). The median was calculated as upper bound, when more 50% of the samples had values above LOQ. Where none of the samples had values above LOQ, the maximum value was set at LOQ. Method LOQs are given in the last column.

		Atlantic salmon	Rainbow trout	Arctic char	Atlantic cod	Atlantic halibut	Turbot	LOQ
PBDE	***n***	***98***	***4***	***2***	***1***	***1***	***1***	
	n >LOQ	98	4	2	0	1	1	
	Median	0.0082	0.0098	0.012	-	-	-	

PBDE 28		**Atlantic salmon**	**Rainbow trout**	**Arctic char**	**Atlantic cod**	**Atlantic halibut**	**Turbot**	**LOQ**
PBDE	***n***	***98***	***4***	***2***	***1***	***1***	***1***	
	Max value	0.030	0.012	0.020	LOQ	0.021	0.014	0.00052-0026
	n >LOQ	0	0	0	0	0	0	
PBDE 35	*Median*	-	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	LOQ	0.0010-0.0052
	n >LOQ	98	4	2	1	1	1	
PBDE 47	*Median*	0.13	0.17	0.15	-	-	-	
	Max value	0.29	0.25	0.24	0.0053	0.41	0.26	0.0042-0.021
	n >LOQ	98	4	2	1	1	1	
PBDE 49	*Median*	0.038	0.052	0.031	-	-	-	
	Max value	0.11	0.064	0.051	0.0023	0.11	0.077	0.0010-0.0052
	n >LOQ	71	4	2	0	1	1	
PBDE 66	*Median*	0.0052	0.0066	0.0064	-	-	-	
	Max value	0.014	0.011	0.010	LOQ	0.019	0.013	0.0010-0.0052
	n >LOQ	0	0	0	0	0	0	
PBDE 71	*Median*	-	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	LOQ	0.00052-0026
	n >LOQ	87	2	2	0	1	1	
PBDE 75	*Median*	0.0043	-	0.0034	-	-	-	
	Max value	0.020	0.0070	0.0052	LOQ	0.0082	0.0082	0.00052-0026
	n >LOQ	1	0	0	0	0	1	
PBDE 77	*Median*	-	-	-	-	-	-	
	Max value	0.0092	LOQ	LOQ	LOQ	LOQ	0.0060	0.0065-0.011
	n >LOQ	0	0	0	0	0	0	
PBDE 85	*Median*	-	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	LOQ	0.0010-0.052
	n >LOQ	98	4	2	0	1	1	
PBDE 99	*Median*	0.023	0.025	0.033	-	-	-	
	Max value	0.052	0.046	0.056	LOQ	0.072	0.036	0.0021-0.010
	n >LOQ	98	4	2	0	1	1	
PBDE 100	*Median*	0.033	0.047	0.025	-	-	-	
	Max value	0.084	0.068	0.034	LOQ	0.10	0.072	0.0021-0.010
	n >LOQ	0	0	0	0	0	0	
PBDE 118	*Median*	-	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	LOQ	0.0021-0.010
	n >LOQ	0	0	0	0	1	1	
PBDE 119	*Median*	-	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	0.0071	0.0037	0.0010-0.0052
	n >LOQ	0	0	0	0	0	0	
	Median	-	-	-	-	-	-	
PBDE 120								

PBDE 138		Atlantic salmon	Rainbow trout	Arctic char	Atlantic cod	Atlantic halibut	Turbot	LOQ
PBDE	***n***	***98***	***4***	***2***	***1***	***1***	***1***	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	LOQ	0.0021-0.010
PBDE 153	*n >LOQ*	5	2	0	0	1	1	
	Median	-	-	-	-	-	-	
	Max value	0.012	0.016	LOQ	LOQ	0.023	0.011	0.0021-0.010
PBDE 154	*n >LOQ*	96	4	2	0	1	1	
	Median	0.022	0.036	0.016	-	-	-	
	Max value	0.055	0.069	0.020	LOQ	0.074	0.047	0.0021-0.010
PBDE 183	*n >LOQ*	0	0	0	0	0	0	
	Median	-	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	LOQ	0.0021-0.010
PBDE 196	*n >LOQ*	0	0	0	0	0	0	
	Median	-	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	LOQ	0.00052-0026
PBDE 197	*n >LOQ*	0	0	0	0	0	0	
	Median	-	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	LOQ	0.0031-0.015
PBDE 206	*n >LOQ*	0	0	0	0	0	0	
	Median	-	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	LOQ	0.0031-0.015
PBDE 207	*n >LOQ*	0	0	0	0	0	0	
	Median	-	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	LOQ	0.0031-0.015
PBDE 209	*n >LOQ*	4	0	1	0	0	0	
	Median	-	-	-	-	-	-	
	Max value	0.077	LOQ	0.12	LOQ	LOQ	LOQ	0.0042-0.021

Table 17. Tetrabromobisphenol A (TBBPA) and hexabromocyclododecane (HBCD) (µg/kg w.w.) in fillets of different farmed fish species. The table shows the number of samples analysed per species, number of samples with values above LOQ (n > LOQ), the median, and the maximum concentration measured (Max value). The median was calculated as upper bound, when more 50% of the samples had values above LOQ. Where none of the samples had values above LOQ, the maximum value was set at LOQ. Method LOQs are given in the last column.

		Atlantic salmon	Rainbow trout	Atlantic cod	Artic char	Spotted wolffish	LOQ
	n	***88***	***8***	***2***	***1***	***1***	
TBBPA	*n >LOQ*	7	0	0	0	0	
	Median	-	-	-	-	-	
	Max value	0.67	LOQ	LOQ	LOQ	LOQ	0.04- 0.18
Sum HBCD	*n >LOQ*	81	7	0	1	1	

alpha-HBCD	*Median*	0.035	0.040	-	-	-	
	Max value	0.23	0.11	LOQ	0.18	0.035	0.015- 0.032
beta-HBCD	*n >LOQ*	7	0	0	1	0	
	Median	-	-	-	-	-	
	Max value	0.025	LOQ	LOQ	0.025	LOQ	0.006- 0.028
gamma-HBCD	*n >LOQ*	18	1	0	0	0	
	Median	-	-	-	-	-	
	Max value	0.041	0.0073	LOQ	LOQ	LOQ	0.006- 0.028

3.3.5.2 - Perfluorinated compounds

The results for the analysis of perflourinated compounds (PFAS) are presented in Table 18. There were no MLs for perfluorinated compounds for 2022. However, MLs have been established for PFOS, PFOA, PFNA, PFHxS and the sum of PFOS, PFOA, PFNA and PFHxS from the 1st of January 2023.

Table 18. Perfluorinated compounds (µg/kg w.w.) in fillets of different farmed fish species. The table shows the number of samples analysed per species, number of samples with values above LOQ (n > LOQ), and the maximum concentration measured (Max value) of different perfluorinated compounds.

		Atlantic salmon	***Rainbow trout***	***Brown trout***	***Atlantic cod***	***Atlantic Halibut***	***LOQ***
	n	***101***	***6***	***1***	***1***	***1***	
*PFBA**	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	1
PFBS	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	1
PFDA	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.2
PFDoDA	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.2
PFDS	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.2
PFHpA	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.2
PFHxA	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.5
PFHxS	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	1
PFNA	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.2
PFOA	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.6
PFOS	*n >LOQ*	0	0	0	0	1	
	Max value	-	-	-	-	0.4	0.2

PFOSA	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	0	0.5
PFTeDA	*n >LOQ*	0	0	0	0	-	
	Max value	-	-	-	-	0	0.2
PFTrDA	*n >LOQ*	0	0	0	0	-	
	Max value	-	-	-	-	0	0.2
PFUdA	*n >LOQ*	0	0	0	0	-	
	Max value	-	-	-	-	0	0.2
*Two samples from *Atlantic salmon* are lacking results							

3.3.5.3 - Polycyclic aromatic hydrocarbons (PAHs)

The results for PAH are summarised in Table 19. There is no maximum limit for PAH in fresh fish (Commission regulation (EU) No 835/2011).

Table 19. Polycyclic aromatic hydrocarbons (µg/kg w.w.) in fillets of different farmed fish species. The table shows the number of samples analysed per species, number of samples with values above LOQ (n >LOQ), and the maximum concentration measured (Max value) of different polycyclic aromatic hydrocarbon compounds. Method LOQs are given in the last column.

PAH		Atlantic salmon	Rainbow trout	Brown trout	Atlantic cod	Atlantic halibut	LOQ
	n	***89***	***6***	***1***	***1***	***1***	
5-methylchrysene	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.02 - 0.13
Benz(a)anthracene	*n >LOQ*	3	1	0	1	0	
	Max value	0.44	0.48	-	0.087	-	0.065 – 0.12
Benzo(a)pyrene	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.02 - 0.13
Benzo(b)fluoranthene	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.02 - 0.13
Benzo(c)fluorine	*n >LOQ*	1	0	0	0	0	
	Max value	0.13	-	-	-	-	0.02 - 0.13
Benzo(ghi)perylene	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.02 - 0.13
Benzo(j)fluoranthene	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.02 - 0.13

Benzo(k)fluoranthene	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.02 - 0.13
Chrysene	*n >LOQ*	12	1	0	1	0	
	Max value	0.76	0.73	-	0.14	-	0.065 – 0.13
Cyclopenta(cd)pyrene	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.02 - 0.13
Dibenz(ah)anthracene	*n >LOQ*	5	0	0	0	0	
	Max value	0.43	-	-	-	-	0.02 - 0.13
Dibenzo(a,e)pyrene	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.09-0.70
Dibenzo(a,h)pyrene	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.09-0.70
Dibenzo(a,i)pyrene	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.09-0.70
Dibenzo(a,l)pyrene	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.09-0.70
Indeno(1,2,3,-cd)pyrene	*n >LOQ*	0	0	0	0	0	
	Max value	-	-	-	-	-	0.02 - 0.13

3.3.5.4 - Ethoxyquin

Ethoxyquin (EQ) and ethoxyquin dimer (EQDM) levels were measured in a total of 69 pooled samples (Table 20) from Atlantic salmon (57 samples), rainbow trout (7 samples), Atlantic cod (2 samples), Atlantic char (2 samples) and turbot (1 sample). None of the samples contained EQ or EQDM at levels above the LOQs.

Table 20. Ethoxyquin and ethoxyquin dimer (mg/kg w.w.) in fillets of different farmed fish species. The table shows the number of samples analysed per species, and the number of samples with values above LOQ (n > LOQ). Method LOQs are given in the last column.

		Atlantic salmon	**Rainbow trout**	**Atlantic cod**	**Arctic char**	**Turbot**	***LOQ* (mg/kg w.w.)**
	n	***57***	***7***	***2***	***2***	***1***	
Ethoxyquin	n >LOQ	*0*					*0.001*
Ethoxyquin dimer	n >LOQ	*0*					*0.005*

4 - Conclusions

No residues of substances with anabolic effect or unauthorized substances were detected in any of the samples analysed.

Residues of the authorized anti-sea-lice agents emamectin, lufenuron and imidacloprid were detected, in addition cypermethrin and deltamethrin, which can be used both as anti-sealice agents and plant protection agent was found. However, the concentrations for all of the residues were well below the respective MRLs for the compounds.

As for the previous years, no residues of antibiotics, endoparasitic agents or sedatives were detected in any of the samples.

For contaminants, none of the samples exceeded the EUs maximum levels, where such levels have been established (sum dioxins, sum dioxins and dl-PCBs, PCB-6, mercury, lead and cadmium).

5 - References

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Commission regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs.

Commission regulation (EU) No 835/2011 of 19 August 2011 amending Regulation (EC) No 1881/2006 as regards maximum levels for polycyclic aromatic hydrocarbons in foodstuffs.

Commission Regulation (EU) No. 37/2010 on pharmacologically active substances and their classification regarding maximum residue limits in foodstuffs of animal origin.

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89/662/EEC, 90/425/EEC, 91/496/EEC, 96/23/EC, 96/93/EC and 97/78/EC and Council Decision 92/438/EEC (Official Controls Regulation).

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6 - Appendix

Table A 1 . Calculations of sums for certain pesticides based on molecular weights according to EU DG SANTE (2017).

Sum	Substances included in the sum	Conversion factor
DDT (sum of p,p-DDT, o,p-DDT, p,p-DDD, o,p-DDD, p,p-DDE,and o,p-DDE expressed as DDT)	op-DDT	1
	pp-DDT	1
	op-DDD	1.108
	pp-DDD	1.108
	op-DDE	1.115
	pp-DDE	1.115
DDT (sum of p,p´-DDT, o,p´-DDT, p-p´-DDE and p,p´-DDD expressed as DDT) [1]	op-DDT	1
	pp-DDT	1
	pp-DDD	1.108
	pp-DDE	1.115
Endosulfan (sum of alpha- and beta-isomers and endosulfan-sulphate expressed as endosulfan) [2]	alpha-endosulfan	1
	beta-endosulfan	1
	endosulfan sulphate	0.962
Aldrin and dieldrin (Aldrin and dieldrin combined expressed as dieldrin) [3]	dieldrin	1
	aldrin	1.044
Chlordane (sum of cis- and trans-isomers and oxychlordane expressed as chlordane)	trans-chlordane	1
	cis-chlordane	1
	oxychlordane	0.967
Chlordane (sum of cis- and trans-chlordane) [1]	trans-chlordane	1
	cis-chlordane	1
Heptachlor (sum of heptachlor and heptachlor epoxide expressed as heptachlor) [1]	heptachlor	1
	trans-heptachlor epoxide	0.959
	cis-heptachlor epoxide	0.959
Toxaphene (sum of Parlar No 26, Parlar No 50 and Parlar No 62) [4]	Toxaphene 26	1
	Toxaphene 50	1
	Toxaphene 62	1

[1] Legal residue definition according to Reg. (EC) No 149/2008.

[2] Legal residue definition according to Reg. (EU) No 310/2011.

[3] Legal residue definition according to Reg. (EC) No 839/2008.

[4] Legal residue definition according to Reg. (EU) 2015/868; Campechlor (Toxaphene).

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